

Northern bog lemming survey

1995

A Report to:

USDI Bureau of Land Management

**Garnet Resource Area
3255 Fort Missoula Road
Missoula, MT 59801**

Submitted by:

James D. Reichel

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*Montana Natural Heritage Program
1515 E. Sixth Avenue
P. O. Box 201800
Helena, MT 59620-1800*

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ABSTRACT

During the 1995 field season, small mammals were surveyed for at 4 sites; no northern bog lemmings (*Synaptomys borealis*) were caught. The four sites were the most suitable sites seen in the Garnet Resource Area, but were not of exceptionally high quality. The total number of known bog lemming sites in Montana is 17, the most sites in any of the lower 48 states. Known sites in Montana range in size from 1 to approximately 340 acres. The best habitat predictor for potential northern bog lemmings sites in Montana is the presence of large, thick moss mats, particularly sphagnum moss.

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INTRODUCTION

The northern bog lemming (*Synaptomys borealis*), a small, grayish brown, vole-like microtine, is related to the true arctic lemmings (*Lemmus*). Nine poorly differentiated subspecies are currently recognized (Hall 1981). The northern bog lemming has a total length of 118-140 mm including its very short tail (19-27 mm) (Banfield 1974, Hall 1981). The combination of a tail less than 28 mm long and a longitudinal groove in the upper incisors distinguish the northern bog lemming from all other mice found in Montana.

Little is known about northern bog lemming life history. Litter sizes vary from 3-8, with 2 (or more?) litters per year. It has been suggested that some animals breed the same year they are born (60-90 days old?). Such information is scattered throughout the literature. All literature on specific to northern bog lemmings deals mainly with distribution; other publications mention lemmings only as a sidelight to the main publication (Appendix 1).

The northern bog lemming is boreal in distribution, occurring in North America from near treeline in the north, south to Washington, Idaho, Montana, Minnesota, and New England. It typically inhabits sphagnum bogs and fens, but is also occasionally found in other habitats including mossy forests, wet sub-alpine meadows, and alpine tundra. One subspecies (*S.b. artemisiae*) lives on sagebrush hillsides in eastern British Columbia (Anderson 1932). Southern bog lemmings (*S. cooperi*) also inhabit a wide variety of habitats, all of which are marginal for *Microtus*; bog lemmings may be competitively excluded from better quality habitats by *Microtus* (Doutt et al. 1973, Linzey 1981). The northern bog lemming is rarely trapped and is one of the least known mice in North America. It is listed as a Species of Special Concern by the Idaho and Montana Natural Heritage Programs (Moseley and Groves 1990, Reichel 1995).

A few relict populations occur in the lower 48 states; the subspecies *chapmani* occurs in Montana, Idaho, and northeast Washington (Hall 1981). Bog lemmings are known from 4 locations in Idaho and 8 in Washington, all from within 80 km of the Canadian border (Johnson and Cheney 1953, Wilson et al. 1980, Reichel 1984, Groves and Yensen 1989, D. Johnson pers. comm.). The reasons for the disjunct nature of the populations may include: 1) the localized nature of its primary habitat; and 2) the currently patchy distribution of a boreal species that was more widely distributed during the Pleistocene (a glacial relict).

Prior to 1992, evidence of bog lemmings in Montana included: 1) 6 locations on the west side of Glacier National Park (Wright 1950, Weckwerth and Hawley 1962, Hoffmann et al. 1969, Pearson 1991); 2) Shoofly Meadows in the Rattlesnake drainage north of Missoula (Adelman 1979), and 3) a single skull recovered from a Boreal Owl (*Aegolius funereus*) pellet west of Wisdom (J. Jones pers. comm.); where the owl captured the lemming was unknown. In 1992 and 1993, 51 sites were trapped which located 10 new populations of northern bog lemmings (Figure 1) (Reichel and Beckstrom 1993, 1994). The Maybee Meadows site is the southern-most known population of the species outside of New England and one of two Montana populations known from east of the Continental Divide. All 10 sites found in 1992-1993 were associated with thick mats of moss.

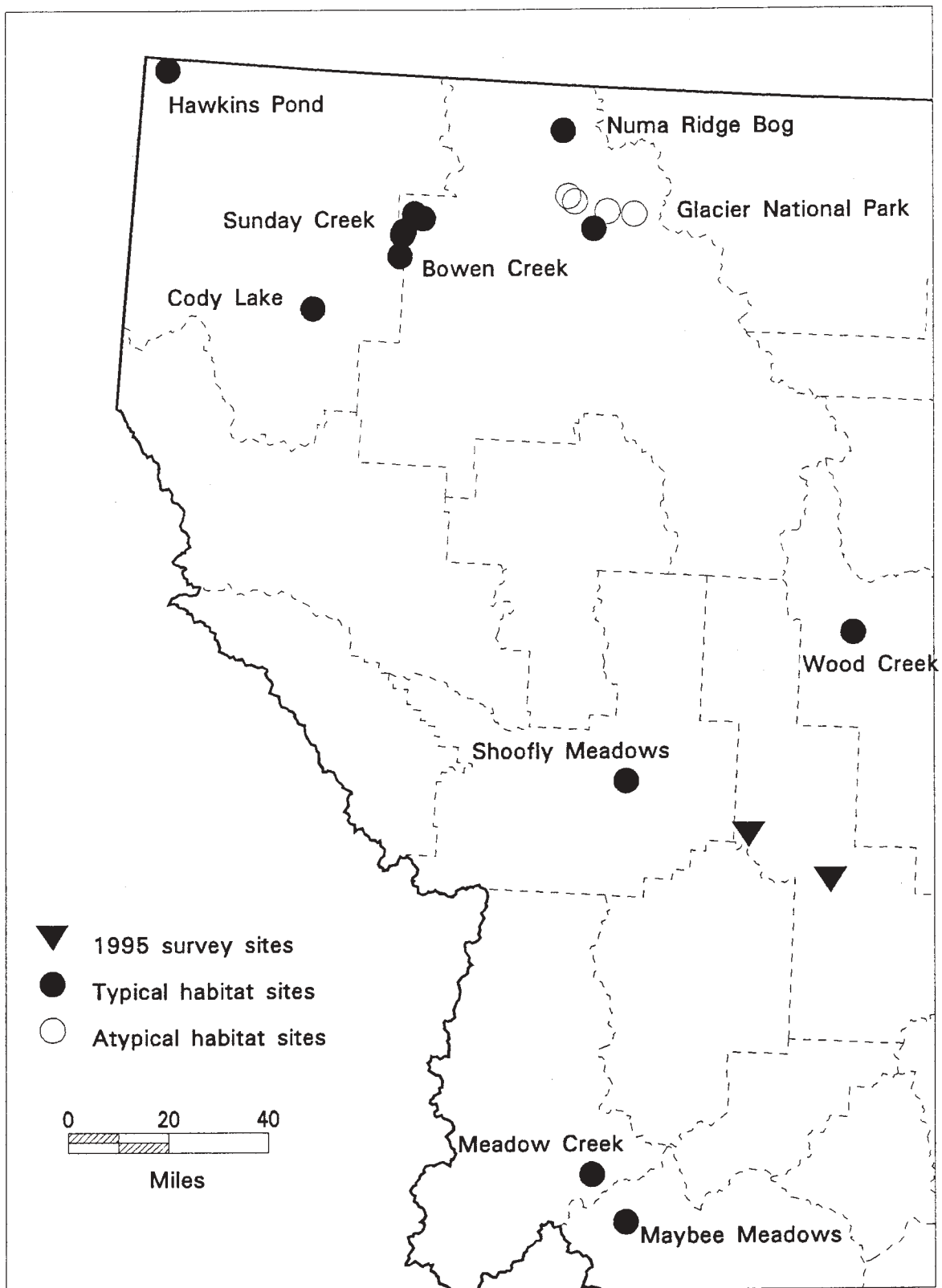


Figure 1. Northern Bog Lemming occurrences in Montana.

Locations from Wright (1950), Weckwerth & Hawley (1962), Adelman (1979), Pearson (1991), and Reichel & Beckstrom (1993, 1994)

A multi-year study of northern bog lemmings in Montana was begun in 1992. Objectives during 1995 included:

- 1) surveying at least 4 sites with potential habitat for bog lemmings in northwest Montana on the Garnet Resource Area; and,
- 2) updating an annotated bibliography of northern bog lemming literature.

METHODS AND MATERIALS

I visited 12 sites on or near Bureau of Land Management lands on the Garnet Resource Area (BLM-GRA) in western Montana, examining riparian habitats to determine their suitability for northern bog lemmings. The four most suitable sites were trapped (Table 1), while eight additional sites were examined but not trapped. These sites included (Table 2): very small riparian areas; standing water with only very narrow fen border; homogeneous vegetation (sedges only for example) lacking moss mats; or cattail marshes. Most sites examined were suggested by biologists and others from the Bureau of Land Management and Montana Natural Heritage Program; several others were identified while in the field or by examining maps of the general area.

From 21 - 25 August 1995 Museum Special snap-traps were used to sample 4 sites on the BLM-GRA. Traps were baited with a combination of peanut butter and rolled oats, either alone or with E. J. Dailey's muskrat lure. Two traps with different baits were placed within 2 m of each other at each station. We placed each trap at a station to maximize success (runway, burrow, etc.). Stations were placed 5-30 m apart.

Trapping effort ranged from 204 to 230 trap-nights over 2 nights. A trap-night constitutes one trap set for one 24-hour period (traps sprung and empty, or completely missing, are not counted).

RESULTS

Northern bog lemmings were not captured at any of the four sites trapped (Tables 1). At each site however, 1-5 species of other small mammals were captured (Table 3). These included masked shrews (*Sorex cinereus*), vagrant shrews (*Sorex vagrans*), water shrews (*Sorex palustris*), western jumping mice (*Zapus princeps*), meadow voles (*Microtus pennsylvanicus*), montane voles (*Microtus montanus*) and red-backed voles (*Clethrionomys gapperi*). Some shrews will need the preliminary field identification verified when the skulls are cleaned.

Table 1. Sites trapped during 1995 northern bog lemming surveys on the BLM Garnet Resource Area.

Site	Location	Elevation	Date	Trap-nights
Upper Chamberlain Meadows, Powell Co.	T13N R13W S8 SW¼	5980	23-25 Aug	204
Lower Chamberlain Meadows, Powell Co.	T13N R13W S8 NW¼	5940	23-25 Aug	204
Upper Wet Cottonwood Creek, Powell Co.	T11N R10W S9 SE¼	6800	21-23 Aug	229
Cottonwood Meadows, Powell Co.	T11N R10W S10 NW¼	6650	21-23 Aug	230

Table 2. Sites examined for northern bog lemming habitat, but found unsuitable or only marginally suitable.

Site	Location	Comment
Upper Wales Creek, Powell Co.	T13N R13W S17 NE¼	No moss mats; riparian
Upper Wales Creek, Powell Co.	T13N R13W S16 NW¼	No moss mats; riparian
West Chamberlain Meadows	T13N R13W S18 NE¼	No moss mats; mostly dry
Cap Wallace Gulch, Powell Co.	T13N R14W S9	No moss mats; riparian
Brazeil Lake, Powell Co.	T12N R10W S22 NE¼	No moss mats; marsh
Brazeil Creek, Powell Co.	T12N R10W S22	No moss mats; riparian/dry
Lower Wet Cottonwood Creek	T12N R10W S33	No moss mats; riparian/dry
Upper Brock Creek, Powell Co.	T11N R10W S16 NE¼	No moss mats; riparian

Table 3. Results of snap trapping during 1995 northern bog lemming surveys.

Site	Trap	<u>Total number of each species¹ caught</u>							
	Nights	SOPA	SOVA	SOCI	SOSP	MIPE	MIMO	CLGA	ZAPR
Upper Chamberlain Meadows	204			9	3	28	1	1	
Lower Chamberlain Meadows	204	1	7	4		50		3	
Upper Wet Cottonwood Creek	229					13	4	1	1
Cottonwood Meadows	230					23			
Grand Total	867	1	7	13	3	114	5	5	1

¹SOPA=*Sorex palustris*; SOVA=*Sorex vagrans*; SOCI=*Sorex cinereus*; SOSP=*Sorex* spp.; MIPE=*Microtus pennsylvanicus*; MIMO=*Microtus montanus*; CLGA=*Clethrionomys gapperi*; ZAPR=*Zapus princeps*.

DISCUSSION

Distribution. While northern bog lemmings were not found on the BLM-GRA, it is within their range in Montana which includes from the northwest corner of the state east to the Rocky Mountain Front, and south through the mountains to Lost Trail Pass on the Continental Divide (Figure 1). The Maybee Meadows site is the southern-most site known for the species outside of New England; two sites in New Hampshire are about 160 km farther south (Clough and Albright 1987; Reichel and Beckstrom 1993, 1994). The Maybee Meadows and the Wood Creek sites are the only known northern bog lemming sites east of the Continental Divide in Montana. We expect additional populations to be found across western Montana, perhaps as far south as Yellowstone National Park, and possibly east to mountain ranges such as the Belt or Snowy ranges. The known elevation range for Montana is from 3340 ft (McDonald Creek, Pearson 1991) up to 6520 ft (Maybee Meadows, Reichel and Beckstrom 1993).

Detectability. The habitat in the BLM-GRA appears to be very limited for northern bog lemmings. The best 4 of the 12 sites seen were trapped; trapping intensity was probably sufficient to detect lemmings had they been present. Unless areas with larger moss mats are found on the BLM-GRA more surveys are not warranted at this time. Trapping effort at each site ranged from 204 to 230 trap-nights over 2 nights. Previous snap-trap effort required to document bog lemming presence (at sites found to contain the species) averaged 114 trap-nights, and ranged from 46 trap-nights (during 1 night) to 224 trap-nights (during 3 nights of trapping) (Reichel and Beckstrom 1992, 1993).

During 1992-1993 lemmings were found at 10 of 17 sites that appeared to have suitable lemming habitat. Either the lemmings are at those sites and we failed to detect them, or we sampled some sites with apparently good habitat, which actually lacked lemmings. Probably a combination of the two is actually the case (Reichel and Beckstrom 1993, 1994). The percentage of sites with good habitat which had lemming captures was slightly higher than that of Pearson (1991) who found lemmings at 3 of 11 bog/fen sites trapped with Sherman live traps in 1989-90.

Habitat Patches. Bog lemmings have been found in at least nine community types (Table 4), including some of those present at the four sites trapped on the BLM-GRA in 1995. However, peatland communities constitute a very small proportion of the landscape in Montana and have not been adequately classified (Bursik and Moseley 1992). Whether new information on these fens will result in newly defined community types which closely approximate habitat used by northern bog lemmings remains to be seen. Extensive thick moss mats were present in all but one of the lemming sites found during our previous surveys (Reichel and Beckstrom 1993, 1994), and were also present at Numa Ridge Bog, McGee Meadows (Pearson 1991, P. Lesica pers. comm.) and Shoofly Meadows (Pearson 1991, S. Chadde pers. comm.).

In 1993 I spent several hours along Camas Creek in the vicinity of the first lemming population known from the state (Wright 1950) and found only scattered clumps of moss.

Table 4. Plant communities present at 6 northern bog lemming sites.

Community\\phase	Sunday Creek	Cody Lakes	Bowen Creek	Wood Creek	Maybee Meadows	Meadow Creek
Abies lasiocarpa						
\\Calamagrotis canadensis	yes					
Picea						
\\Salix geyeriana- Carex utriculata				yes		
Salix drummondiana	yes					
Salix planifolia- Salix wolfii						
\\Carex aquatilis					yes	
Betula glandulosa						
\\Carex utriculata					yes	
Betula glandulosa- Eleocharis pauciflora						
\\Carex lasiocarpa		yes				
Betula glandulosa- Carex lasiocarpa			yes			
Carex utriculata (=C. rostrata)					yes	yes
Eleocharis pauciflora		yes				

Weckwerth and Hawley (1962) did not adequately describe the two specific sites where they captured bog lemmings, but they were visited by D. E. Pearson (pers. comm.) who found they were not located in fens or covered by thick moss mats. At these three sites trapping was conducted multiple years, often twice each year (Camas Creek: 18 yrs [Hoffmann et al. 1969]; Anaconda #1: 6 yrs spring and fall [Jonkel 1959]; Anaconda #6: 4 yrs spring and fall [Jonkel 1959]). Despite this intensive trapping, only a total of 3 individuals have been taken in Camas Creek in 2 of 18 years, and 1 individual at each of the two Anaconda Creek sites. A similar situation exists with the McDonald Creek site which is in old-growth western hemlock (*Tsuga heterophylla*) forest (Pearson 1991); this site has been trapped multiple times yielding only a single lemming (June 1991 - September 1993, total 3600 trap-nights, D. E. Pearson, pers. comm.). Apparent high quality habitat patches exist within 7 km of all four sites (Table 9, 10; Pearson 1991; P. Lesica, pers. comm.). It seems likely that these sites are very marginal, and/or that the individuals were found while dispersing from a nearby high quality site.

Other habitat descriptions of *S. b. chapmani* trapping sites in the northern Rocky Mountains have sometimes included mention of sphagnum moss (Layser and Burke 1973, Groves and Yensen 1989) while others have not (Wilson et al. 1980). I captured a single juvenile male lemming on a dry alpine/subalpine ridge in northeast Washington (Wilson et al. 1980).

Areas with extensive moss mats, particularly sphagnum, are the most likely sites in which to find new bog lemming populations in Montana. Other habitats in Montana may either support lower densities of bog lemmings; be used primarily by dispersing individuals; be used during specific seasonal, climatic, or competitive situations; or be population sinks. Marginal habitats and areas may be important to maintain population viability. The only certainty is that there is much to be learned about habitat use by northern bog lemmings.

Patch size of known bog lemming sites in Montana varies from 1-340 acres, with 7 of 13 being less than 10 acres (Table 5). No patch sizes are known for 4 sites since they are not in typical habitat (see preceding paragraph). Most sites found thus far in Montana appear to be patches within potentially larger metapopulation patch complexes. These could include: a Sunday Creek complex with a Bowen Creek complex; a Maybee Meadows complex possibly with the Meadow Creek patch; and a McGee Meadows complex which may be part of a larger complex in Glacier National Park. However, several small patches appear to be isolated. Numa Ridge Bog (3 ac) is 5 km from the nearest fen/bog patch (Pearson 1991). Shoofly Meadows is larger (24 ac) but may be 14 km from another suitable patch. Wood Creek is certainly at the extreme, having only about 2 ac of moss mat habitat and being 13 km from the nearest known potential site. While there appears to be substantial amounts of marginal habitat along Wood Creek which might support bog lemmings, much of the riparian habitat has been heavily impacted by domestic livestock grazing.

This leads to questions about what constitutes a viable population of northern bog lemmings. Three (somewhat) alternative hypotheses could apply: 1) lemmings live in habitat patches which have been isolated for thousands of years; 2) lemmings move substantial distances between patches supplementing (or recolonizing) the sub-population within a patch and contributing genetic material; and 3) lemmings use habitats other than moss bogs/fens.

Table 5. Characteristics of known bog lemming sites, plus several additional sites in the Sunday Creek complex, in Montana.

Site	Location	Elevation (ft)	Size ¹ (ac)	Distance to nearest site	
				Known (km)	Potential (km)
Hawkins Pond	T37N R33W S18	6200	5	602	?
Numa Ridge Bog	T36N R20W S21	5040	2-4	23	5
Anaconda Creek West	T34N R20W S27	3600	? ³	2.8	<6.9
Anaconda Creek East	T34N R20W S36	3600	? ³	2.8	<6.9
Camas Creek	T33N R19W S12	3800	? ³	11	<6.5
McGee Meadows	T33N R19W S27	3870	340	6.5	<3.2
McDonald Creek	T33N R18W S12	3422	? ³	8.9	4
Sunday Creek complex	T32-33N R25-26W	4220-4800	210	6.6	6.4
Site 1	T33N R25W S25	4220	23	1	0.2
Site 5	T32N R26W S13	4800	30	0.3	0.3
Site 6	T32N R26W S12	4680	5	0.3	0.3
Paul Creek	T33N R25W S27	4440	61	1.7	1
*Site 2	T33N R25W S26	4230	6	0.5	0.5
*Site 3	T32N R25W S5	4300	45	2.6	0.6
*Site 4	T32N R25W S6	4460	16	2.3	0.5
Bowen Creek	T31N R26W S1	4760	23	6.6	0.2
lower Cody Lake	T29N R28W S6	4700	6	32	?
Wood Creek	T20N R10W S26	5590	2	90	<13
Shoofly Meadows	T14N R17W S4	5880	24	90	<14
Meadow Creek	T01N R18W S10	5920	1	19	<18
Maybee Meadows	T01S R17W S26	6520	8	19	1.8

* Sites in Sunday Creek complex with suitable habitat, but no bog lemmings trapped in 115-215 trap-nights per site

¹ Size of habitat patch, or patches with less than 100 m separation between patches

² nearest site at Cow Creek, Idaho

³ site lacks typical bog lemming habitat with deep moss; see text.

Alternative 1. Populations within patches such as Wood Lake and Numa Ridge Bog would not appear to have been able to survive given the small habitat patch size, if they are indeed totally isolated and if lemmings do not use habitats other than moss mats. This leads us to think that this alternative is not completely feasible.

Alternative 2. In several areas such as the Sunday Creek complex, the distribution and size of known patches suggests movement between patches. The overall view that most patches in Montana are relatively near other known, or potential, patches, gives support to this hypothesis. Arctic lemmings are known to make spectacular movements during highs in the population cycle; this could also be true of northern bog lemmings. Northern bog lemmings do undergo population fluctuations at least in central Canada (Edwards 1963). However, population cycles in general appear to be less dramatic in: 1) more southerly areas, and 2) in areas with less contiguous habitat for the cycling species.

Alternative 3. Lemmings have certainly been found in habitats other than bogs/fens in Montana and in other areas of their range. In the Montana sites where the habitat is atypical, captures represent a rare event. Multiple trapping periods prior to and/or following the capture have not resulted in regular additional captures of lemmings. In Glacier National Park, general trapping for small mammals over nearly 100 years in numerous habitats has resulted in captures of 5 lemmings at 4 sites (all atypical habitats) (Wright 1950, Hoffmann et al. 1969, Weckwerth and Hawley 1962, Pearson 1991). In the rest of Montana, only 1 site has been found during general small mammal trapping (Shoofly Meadows, a typical habitat site) (Adelman 1979). However, when trapping focused on bog/fen habitat, 12 new sites were discovered in the past 4 years (Pearson 1991, Reichel and Beckstrom 1993, 1994). Many of these sites have had multiple animals captured in a single night, supporting the premise that the fen/bog habitat is the primary habitat for northern bog lemmings in Montana. The extent of lemming use of other habitats has yet to be determined, but would appear to be low.

Probably all three alternatives have some element of reality. It seems likely that 1) some patch complexes are isolated from others and have been for long periods of time; 2) some relatively long distance movements may increase gene flow, supplement small populations, and allow for recolonization of extirpated patches; and 3) while bog lemmings use a variety of habitats to a limited (and largely unknown) extent, bog and fen habitats hold the densest populations of lemmings.

Research Methods. How do we get the information on distribution, habitat use, and movement that we need to manage this species? Distributional information, and to a lesser extent habitat use, has often been gathered using snap-traps. Detailed habitat use and movement data for small mammals are most commonly obtained using mark-recapture techniques with live traps. However, for northern bog lemmings, live traps are of very limited usefulness. This is because Sherman live-trap use: 1) is labor intensive throughout the trapping period; 2) has very low success with any bait tried; and 3) results in at least some mortality (4 of 6 known captures) (Pearson 1991, Reichel and Beckstrom 1993). Pitfalls, used as live traps: 1) are labor intensive especially during placement; 2) cannot be used in the saturated soil situations commonly encountered in bog lemming habitat; and 3) result in at least some mortality during and between trapping periods. Given these drawbacks, it seems doubtful that live-trapping

methods, by themselves, will yield much information on habitat use, population parameters, movements, or home range sizes. Incidental mortalities may be a significant factor over a study long-term enough to yield good information. Additionally, live-trapping to initially find populations will require at least 10 times the effort and cost when compared to snap-trapping, still causing some mortality. Given the very low Sherman live-trapping success, negative results for even 1000 trap-nights per site would not provide much confidence that lemmings are not present.

Dropping boards may provide one option, but we think differentiating northern bog lemming dropping from other voles will be difficult. Jones and Birney (1988) report that northern bog lemming droppings are bright green while other vole droppings are brown or black. However, we found that at least some bog lemmings had brown droppings. If color alone is used to differentiate the droppings, it may lead to serious biases. Pearson (1991) was not confident of identification of droppings (*Microtus* versus *Synaptomys*) in a test of the technique in Glacier National Park. He did speculate that it could be possible using more sophisticated identification techniques.

Snap-trapping for bog lemmings was much more successful than live-trapping and only 3 females were captured using this method (at all locations in Montana in 1992 and 1993). It appears to be the method of choice for initial survey work to find new populations, both from an economic and time-constraint view. Concerns have been expressed that snap-trapping is not a suitable technique to use on a “sensitive species.” This argument may have some validity from a public perception point of view, but has little or no biological basis (Reichel and Beckstrom 1993).

Very small radio-telemetry packages have recently been used to study other voles and this technique seems to hold the most promise for studying *Synaptomys*. It would require relatively few individuals to be captured and recapture of those individuals would not be necessary. It would seem to be the method of choice for examining activity patterns, habitat selection and use, home range size, and typical movements by *Synaptomys*.

Long range movements, such as dispersal, are more difficult to determine using radio-telemetry. This is due to 1) the relative rarity of such movements; and 2) time and equipment limitations for finding animals moving far from their expected location. Indirect means of determining the amount of inter-patch movement are available using biochemical analyses of various types to measure gene flow. This may be a viable approach to learning about inter-patch movements and gene flow.

STATEWIDE MANAGEMENT RECOMMENDATIONS AND RESEARCH NEEDS

Based on limited observations at the sites where bog lemmings have been found, several interim management recommendations can be made. I feel that these are the minimum necessary to maintain viable bog lemming populations. Additional research is needed which may lead to other management actions necessary for maintaining viable bog lemming populations.

- 1) Lacking surveys at specific sites, assume northern bog lemmings are present at sphagnum or other fen/bog moss habitat patches in north Idaho and western Montana during land management planning processes.

- 2) Do not harvest timber within 100 m of sphagnum or other fen/bog moss mats or associated riparian areas which could provide corridors for inter-patch movements.
- 3) Minimize domestic livestock grazing in drainages with unsurveyed moss mats present. Range conditions in riparian areas with moss mats should be maintained in good to excellent categories. Stocking rates should be reduced to a point where rapid recovery occurs if either 1) current range condition is fair or poor; or 2) livestock are impacting moss mats.
- 4) No management activities which could destroy moss mats should be undertaken. Examples could include (but are not limited to): 1) road building in, or in some cases upslope from, bogs/fens; 2) pothole blasting in bogs/fens; 3) trail construction across or adjacent to bogs/fens; 4) dam construction upstream from bogs/fens, or downstream if flooding of bogs/fens would occur; and 5) snowmobile use in bogs/fens which could compact vegetation or collapse lemming runways or nests.

Very little information is available on the northern bog lemming. Even the distribution in the U.S. is poorly understood; most populations have been found within the past 15 years. Habitat use by northern bog lemmings has never been determined in any systematic way. Descriptions of habitat consist of anecdotal accounts of where each specimen has been captured; only about 35 individuals had been collected in the Pacific Northwest prior to 1990. Reichel and Beckstrom (1993, 1994) contain detailed vegetative descriptions for six lemming sites in Montana. Food habits and reproductive information in the literature is also limited to a very few anecdotal accounts. Analysis of food from stomachs of bog lemmings captured at six sites in western Montana show mosses composed 29-92% of the diet (by volume) with Sphagnum moss averaging <1%; sedges (1-64%) and grasses (0-8%) composed most of the rest of the diet (Reichel, unpubl. data). No information is available on such subjects as movements, population densities, longevity, or home range. Much additional research is required to make intelligent land management decisions where northern bog lemmings are present. We recommend the following as the highest priority needs:

- 1) Conduct additional surveys to better understand macro- and micro- distribution in Montana; on a state-wide basis this should include surveys on the Dillon Resource Area, Headwaters Resource Area, Helena National Forest, Deerlodge National Forest, Gallatin National Forest, Custer National Forest, Lewis and Clark National Forest (Jefferson Division), and sites on the Beaverhead National Forest south and east of Maybee Meadows.
- 2) Analyze all stomachs of bog lemmings collected to provide additional food habits information; this should give some indication of potential habitat use.
- 3) Conduct plant community surveys at all known bog lemming locations. This should include identification of dominant mosses present.
- 4) Gather information on the autecological requirements of the mosses found at bog lemming sites.
- 5) Carry out research on northern bog lemming habitat use. Given the extreme difficulty in capturing the northern bog lemming, radio-telemetry is probably the only viable means to obtain satisfactory answers as to how bog lemmings use habitat within their home ranges.
- 6) Carry out research on northern bog lemming movements to gather information on home ranges and possibly dispersal. This information needs to be integrated with simultaneously collected habitat use data. Again, we feel radio-telemetry is the only viable methodology available.

- 7) Carry out biochemical research on allelic diversity and gene flow between habitat patches. It is possible that hair/skin from specimens already collected could be used for analysis. This should be done utilizing information on patch size and isolation, across the range of the lemming in Montana. Ideally, Montana information should be compared to information from a population in Canada at a site with relatively continuous habitat over a large area.

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- Jones, J. K., Jr. and E. C. Birney. 1988. Handbook of mammals of the north-central states. U. Minn. Press, Minneapolis.
- Jonkel, C. J. 1959. An ecological and physiological study of pine marten. M.S. Thesis, Montana State Univ., Missoula. 81 pp.
- Layser, E. F. and T. E. Burke. 1973. The northern bog lemming and its unique habitat in northeastern Washington. Murrelet 54:7-8.

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- Pearson, D. E. 1991. The northern bog lemming in Montana and the contiguous United States: distribution, ecology and relic species theory. Unpubl. Senior Thesis, Univ. Mont., Missoula. 33 pp.
- Reichel, J. D. 1984. Ecology of Pacific Northwest alpine mammals. Ph.D. thesis, Washington State Univ., Pullman. 91 pp.
- Reichel, J. D. 1995. Montana animal species of special concern. [Unpubl. list], Mont. Nat. Heritage Prog., Helena. 10 pp.
- Reichel, J. D. and S. G. Beckstrom. 1993. Northern bog lemmings survey: 1992. Montana Natural Heritage Program. Helena, MT. 64 pp.
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- Weckwerth, R. P. and V. D. Hawley. 1962. Marten food habits and population fluctuations in Montana. J. Wildl. Manage. 26(1):55-74.
- Wilson, C., R. E. Johnson and J. D. Reichel. 1980. New records for the northern bog lemming in Washington. Murrelet 61:104-106.
- Wright, P. L. 1950. *Synaptomys borealis* from Glacier National Park, Montana. J. Mammal. 31:460.

APPENDIX 1. ANNOTATED BIBLIOGRAPHY

Adelman, E. B. 1979. A survey of the nongame mammals in the Upper Rattlesnake Creek drainage of western Montana. [M.S. Thesis] University of Montana, Missoula. 129 pp.

Small mammal diversity, niche width and niche overlap were studied in the Upper Rattlesnake Creek drainage, Montana. Snap-trap results, habitat associations and observations are described. For SYNAPTOMYS: habitat was a wet sedge-bluejoint meadow (subalpine fir/bluejoint-bluejoint habitat type); one male caught 9/8/78 in 200 trap-nights; measurements; associated species included: SOREX VAGRANS, CLETHRIONOMYS GAPPERI, and MICROTUS PENNSYLVANICUS.

Allen, J. A. 1903. Mammals collected in Alaska and northern British Columbia by the Andrew J. Stone expedition of 1902. Bull. Amer. Mus. Nat. Hist. 19:521-567.

For SYNAPTOMYS BOREALIS: Describes the Type specimen of SYNAPTOMYS CHAPMANI, sp. nov. (=S. BOREALIS) by an adult male specimen taken in July 1901 in Glacier, B.C. Gives external and skull measurements and pelage description.

Allen, J. A. 1904. Mammals collected in Alaska by the Andrew J. Stone expedition of 1903. Bull. Amer. Mus. Nat. Hist. 20:273-292.

Gives lists of all locations trapped and species at each (arranged in species accounts). 66 SYNAPTOMYS BOREALIS were taken at 5 locations trapped. 1/3 were adults, 4 females and 15 males. Measurements were taken and separated by sex. At Seldovia SYNAPTOMYS was found "most frequently in little marshy meadows, but was also sometimes taken in timber in places like those inhabited by red-backed mice."

Anderson, R. M. 1932. Five new mammals from British Columbia. Natl. Mus. Can. Bull. 70:99-119.

Describes 5 new species of mammals from Canada including Type of SYNAPTOMYS BOREALIS ARTEMISIAE from Stevenson Creek, SW of Princeton at 2400 ft elevation. Known only from Similkameen valley from 2400-5600 ft. Description of color, size, skull. Five individuals (4 males, 1 female) were taken at 2400 ft site, 4 (2 males, 2 females) at a 5600 ft site. The habitat at the lower site is dry Transition zone, with sagebrush, pine grass, and occasional PINUS PONDEROSA. The upper site is Engelmann spruce, subalpine fir, and abundant ground cover including VALERIANA SITCHENSIS, VERATRUM VIRIDE, ANEMONE OCCIDENTALIS, VACCINIUM, LUPINUS, and waist-high dense SALIX. Compares external and skull measurements of subspecies ARTEMISIAE (6Male, 3Female), CHAPMANI (10M, 3F), WRANGELI (2M, 2F), BOREALIS (2M), and DALLI (3?).

Anderson, R. M. 1947. Catalogue of Canadian Recent mammals. Natl. Mus. Can. Bull. 102. 238 pp.

For SYNAPTOMYS BOREALIS: Taxonomic review of specimens by location. Gives 9 subspecies all in single species.

Anderson, R. M., and A. L. Rand. 1943. A new lemming mouse (SYNAPTOMYS) from Manitoba with notes on some other forms. Can. Field-Nat. 57:101-103.

Distribution, measurements, descriptions, and taxonomy.

Anderson, S. 1962. A new northern record of *SYNAPTOMYS BOREALIS* in Ungava. J. Mammal. 43:421-422.

Record of *SYNAPTOMYS* for the Ungava peninsula is a new northern record for the species. Bones of 2 lemmings were found in an owl pellet.

Baker, R. H. 1951. Mammals taken along the Alaska Highway. Univ. Kansas Publ., Mus. Nat. Hist. 5(9):87-117.

Gives lists of all locations trapped and species at each (arranged in species accounts). *SYNAPTOMYS BOREALIS* taken at 2 of 43 locations trapped. At one 30X60 ft grassy area near McIntyre Creek, Yukon, 2250 ft elevation 5 were taken in 66 trap-nights. In thick sedge bordering a small pond at Deadman Lake, Alaska, 1800 ft., one was taken.

Banfield, A. W. F. 1974. The mammals of Canada. University of Toronto Press, Toronto. Reprinted, 1981.

Detailed accounts of 196 species. Includes information on description, habits, habitat, reproduction, ecological status, and distribution. 46 color plates, 100 black and white drawings. *SYNAPTOMYS BOREALIS*: distribution; description; short underground burrows and runways through vegetation; constructs globular nests of grass above ground in winter and below ground in summer; active all winter and throughout 24 hr day; food includes grasses and sedges which are cut into short sections and piled in runways; habitat primarily sphagnum-labrador tea-black spruce bogs but also found in deep mossy spruce woods, wet subalpine meadows, alpine, and sagebrush (one subspp) habitat; breeding season from May-Aug; litters average 4, range 2-8; uncommon in NW Can and rare in E Canada; nine poorly differentiated subspp.

Banfield, F. A. 1941. Notes on Saskatchewan mammals. Can. Field-Nat. 55:117-123?.

Short accounts of new records. *SYNAPTOMYS BOREALIS* was collected (adult male) from the edge of a grassy flat bordering a small marshy bay of Emma Lake.

Bangs, O. 1897. On a small collection of mammals from Hamilton Inlet, Labrador. Proc. Biol. Soc. Wash. 11:235-240.

SYNAPTOMYS BOREALIS collected at Fort Chimo, Labrador; description of single male collected.

Bangs, O. 1898. A list of the mammals of Labrador. Amer. Nat. 32:489-507.

An early list of Labrador mammals. Lists Type specimen of *SYNAPTOMYS INNUITUS* (= *BOREALIS*) from Fort Chimo, Labrador.

Bangs, O. 1900. Three new rodents from southern Labrador. Proc. New England Zool. Club 2:35-41.

Describes Type specimen of *SYNAPTOMYS INNUITUS MEDIOXIMUS* (= *BOREALIS*) from Lance au Loup, Labrador. Adult male with description and measurements.

Beasley, L. E. and L. L. Getz. 1986. Comparison of demography of sympatric populations of *MICROTUS OCHROGASTER* and *SYNAPTOMYS COOPERI*. *Acta Theriologica* 31:385-400.

Both species followed multi-year cycles. Population changes and survival were similar, with lemmings showing less dramatic changes during the cycle.

Beckstrom, S. G. 1993. Food habits of boreal owl during brood-rearing in southwest Montana. Unpubl. ms. 15 pp.

Pellets from 10 nest boxes found *CLETHRIONOMYS GAPPERI* the most important food item (53.6%). *PHENACOMYS INTERMEDIUS* was next most important with 20.7% biomass. Small mammals in general were 99% of prey biomass. 8 *SYNAPTOMYS BOREALIS* were found in 4 nests, comprising 0.7% of the diet.

Booth, E. S. 1947. Systematic review of the land mammals of Washington. Ph.D. Thesis, Wash. State Univ., Pullman.

Good review of knowledge up to that time; has some locations missed by Dalquest (1947). Has information (by subspecies) for all Washington land mammals and includes: dot maps, systematics, taxonomy, descriptions, and habitat. For *SYNAPTOMYS BOREALIS*: shows 2 locations in the North Cascade Mountains. Only subspecies then known was *WRANGELLI* but Booth speculated others would be found farther east (he was right). Description and measurements. Habitat is described as wet, boggy places in the mountains.

Bursik, R. J. 1993. Fen vegetation and rare plant population monitoring in Cow Creek Meadows and Smith Creek Research Natural Area, Selkirk Mountains, Idaho. Cooperative Challenge Cost-share Project, Idaho Panhandle National Forests and Idaho Conservation Data Center, Idaho Department of Fish and Game. 25 pp.

Botanical exploration has revealed that Cow Creek Meadows, on the east slope of the Selkirk Mountains, Idaho, are of extraordinary biodiversity value. Seven rare plant populations are known from the meadows along with one rare animal (Northern Bog Lemming). In addition, grizzly bear and woodland caribou are known to use the drainage during parts of the year. Human activities in the form of cattle grazing, logging, and road building have had an impact on the meadows and are seen as a potential threat to the sensitive plant and animal populations that occur there. In 1992, the Idaho Fish and Game's Conservation Data Center and the Bonners Ferry Ranger District, Idaho Panhandle National Forests, entered into a cooperative agreement to establish monitoring plots in fen habitats of Cow Creek Meadows and Smith Creek RNA to ascertain whether logging and cattle grazing are having negative effects on the sensitive plant populations in Cow Creek Meadows. Smith Creek RNA is the control area for this study. Nine ECODATA plots were placed in the Cow Creek Meadows and four were placed in Smith Creek RNA. An inventory of the vascular and bryophyte floras were made in each area. One hundred and one vascular and bryophyte species occur in the Cow Creek Meadows, making it one of the most floristically diverse peatland systems in Idaho. Reanalysis of Cover Microplot data for each ECODATA plot is recommended at three- to four-year intervals over the next 20 years or more to assess population and habitat trends. Management recommendations are made, including a proposal to establish Cow Creek Meadows as a Special Interest Botanical Area.

Clark, B. K. and D. W. Kaufman. 1990. Short-term responses of small mammals to experimental fire in tallgrass prairie. *Can. J. Zool.* 68:2450-2454.

Short-term response to burning was moving off area by most harvest mice, southern bog lemmings, and prairie voles; deer mice moved onto burned area.

Clough, G. C., and J. J. Albright. 1987. Occurrence of the northern bog lemming, *SYNAPTOMYS BOREALIS*, in the northeastern United States. *Can. Field-Naturalist* 101:611-613.

Three specimens of *SYNAPTOMYS BOREALIS* for Maine and one for New Hampshire are reported. On 18-20 July 1 immature female and 1 adult female (4 embryos) were captured in pitfalls (117 sherman live trap-nights, 108 pitfall trap-nights). Both were captured at 1375 m in a wet sedge meadow dominated by *CAREX*, sphagnum moss, lichen (*CETRARIA NIVALIS*), *SALIX UVA-URSI*, and *BETULA GLANDULOSA*. Associated species at the site were *MICROTUS PENNSYLVANICUS*, *CLETHRIONOMYS GAPPERI*, *PEROMYSCUS MANICULATUS*, *BLARINA BREVICAUDA*, and *SOREX CINEREUS*. A single immature male *SYNAPTOMYS BOREALIS* was captured on 11 Aug in a stand of dead fir and spruce at 400 m elevation. Understory was dominated by fir, spruce, mountain ash, and paper birch; shrub and ground layer was dense raspberry, ferns, some grass and sedge, and sphagnum in scattered damp areas. The area was trapped in 1982 (360 trap-nights), July 1985 (135 Longworth live trap-nights) and Aug 1985 (300 snap trap-nights). Other mammals at this site included *MICROTUS CHROTORRHINUS*, *M. PENNSYLVANICUS*, *CLETHRIONOMYS GAPPERI*, *PEROMYSCUS MANICULATUS*, and *SOREX CINEREUS*. There are now a total of 7 specimens from 4 locations in Maine and New Hampshire.

Coffin, B. and L. Pfannmuller (eds). 1988. Minnesota's endangered flora and fauna. U. Minn. Press, Minneapolis.

Good reference for Minnesota sensitive species with state maps with county of occurrence, status and basis for status, habitat, identification, recommendations, and selected references. *SYNAPTOMYS BOREALIS* summarizes the 5 locations in N MN where lemmings are known. Suggests the species may be difficult to trap. Habitat given as dominated by sphagnum and graminoids; may include forested bogs or open ericaceous shrublands over total range. Recommend additional sampling by qualified professionals and preservation of large tracts of peatlands.

Cowan, I. M., and C. J. Guiguet. 1965. The mammals of British Columbia. *Brit. Columbia Prov. Mus. Handbook* 11. 414 pp.

For *SYNAPTOMYS BOREALIS*: description and measurements; Habitat: usually wet alpine and subalpine meadows; runways and burrows well defined; moves to higher ground in winter; eats sedges, grasses, saxifrages, and other plants; makes small piles of cuttings in runways; deposits droppings in special places where 2 cupfuls may accumulate; 2-8 young per litter, usually 4-5; young born May-Aug; winter nest of dry grass 8" diameter; no citations for any of this information.

Cowan, I. McT. 1939. The vertebrate fauna of the Peace River District of British Columbia. *Occasional Papers B.C. Prov. Mus.* 1.

For *SYNAPTOMYS BOREALIS*: On 28 June found a colony in muskeg and 4 were taken. Habitat was 50 feet square and the "mossy carpet was honeycombed with tunnels." Fecal pellets were strewn about the tunnels, concentrated where feeding was occurring. 1-1.5 inch cuttings of grass were piled throughout the colony. Also caught here were *MICROTUS PENNSYLVANICUS*. Measurements.

Cross, E. C. 1938. *SYNAPTOMYS BOREALIS* from Godbout, Quebec. *J. Mammal.* 19:378.

Single immature taken, with description and measurements.

Dalquest, W. W. 1948. Mammals of Washington. University of Kansas Mus. Nat. Hist. Publ. 2:1-444.

Distributional accounts which include brief descriptions and accounts of habits; dot and associated shading on maps; key to spp. SYNAPTOMYS BOREALIS shows known 2 locations and a possible location (later verified by Wilson, Johnson and Reichel 1980).

Dearden, L. C. 1958. The baculum in LAGURUS and related Microtines. J. Mammal. 39:541-553.

Describes variation in the baculi of LAGURUS. Compares baculi across Microtine genera including LEMMUS, SYNAPTOMYS, DICROSTONYX, CLETHRIONOMYS, PHENACOMYS, and MICROTUS (drawings). SYNAPTOMYS is shown to be most closely related to DICROSTONYX.

Dice, L. R. 1921. Notes on the mammals of interior Alaska. J. Mammal. 2:20-28.

Records of unusual specimens taken in Alaska. Two SYNAPTOMYS BOREALIS taken, one in scrub willows and one in horsetails.

Downing, S. C. 1940. First Ontario record of the subgenus MICTOMYS. Can. Field-Nat. 54:109-110.

One immature male 25 July 1939 at Moosonee, Ontario. Taken on an open bank of a small creek draining a bog. Surrounding area had spruce trees and deep mossy ground cover. Measurements and description.

Dutcher, B. H. 1903. Mammals of Mt. Katahdin, Maine. Proc. Biol. Soc. Wash. 16:63-72.

Describes 36 mammals known from Mt. Katahdin. For SYNAPTOMYS BOREALIS, 2 were trapped in balsam scrub by a spring at 4500 ft. during >270 trap-nights.

Edwards, R. L. 1963. Observations on the small mammals of the southeastern shore of Hudson Bay. Can. Field-Nat. 77:1-12.

Caught 25 individuals at 5 sites (185 trap-nights); most were caught in open, very wet places. No scat piles or cuttings were associated with this species. Only 2 showed breeding activity, a male with scrotal testes on 23 Aug and a female with 3 embryos on 10 Sept. Most mice appeared to be yearlings. There appeared to be two litters per year, with some young breeding the same summer they were born. Description & measurements.

Foresman, K. R. and D. E. Pearson. 1990. Ecology of the northern bog lemming [abstract]. Sci. Glacier Natl. Park 1990, Ann. Rep. Coop. Park Studies. p. 41.

Relocated lemmings at Shoofly Meadows site [Adelman 1979] and found lemmings in Numa Ridge Bog in 1990.

Gaines, M. S., C. L. Baker and A. M. Vivas. 1979. Demographic attributes of dispersing southern bog lemmings (*SYNAPTOMYS COOPERI*) in eastern Kansas. *Oecologica* (Berlin) 40:91-101.

There was a positive correlation between lemming colonizing removal grids and density of control grids. 41% of losses of control grids were accounted for by dispersal. Residents differed from dispersers by: 1) higher % males; 2) lower % of adult females colonizing grids were in breeding condition; reversed for subadult females; and 3) higher % subadults.

Gaines, M. S., R. K. Rose and L. R. McClenaghan, Jr. 1977. The demography of *SYNAPTOMYS COOPERI* populations in eastern Kansas. *Can. J. Zool.* 55:1584-1594.

Annual and multi-year population cycles were found. Adult and juvenile survival was higher in winter than summer. Breeding was higher in summer than winter, but occurred during both periods.

Garton, E. R. 1977. Late Pleistocene and Recent mammals remains from two caves at Bowden, West Virginia [abstract]. *Proc. W. Virginia Academy Sci.* 49:41.

Found *SYNAPTOMYS BOREALIS* in a limestone cave; no time correlation could be done since they were in a cave-stream deposit.

Godin, A. J. 1977. *Wild mammals of New England*. Johns Hopkins University Press, Baltimore. 304 pp.

Popular account of the mammals of New England. Covers description, distribution, ecology, behavior, age and sex determination, list of specimens examined, records and reports for each species. Literature references and museum sources cited.

Godin, A. J. 1977. *Wild mammals of New England*. Johns Hopkins University Press, Baltimore. 304 pp.

Popular account of the mammals of New England. Covers description, distribution, ecology, behavior, age and sex determination, list of specimens examined, records and reports for each species. Literature references and museum sources cited. *SYNAPTOMYS BOREALIS* "occurs in cold sphagnum bogs, in bluebunch fields matted with weeds, and in dense hemlock and beech woods" [does not match other literature for the area, ie. Clough and Albright 1987]. Lemmings may build runways above ground or burrow in leaf litter. Nest is lined with leaves, grasses, and sometimes fur, and located either above or below ground. May be in small colonies or burrows of other small mammals. Known to eat raspberry seeds and the fungus *ENDOGONE*.

Green, M. M. 1930. Notes on some small Canadian mammals. *Can. Field-Nat.* 44:69.

Two *SYNAPTOMYS BOREALIS* were taken near Pine Falls in Apr 1929. They were in an open tamarack bog with *SOREX HOYI* and *SOREX CINEREUS*. In May 1929 a male was taken 50 miles north of Pas and had side glands 11X7 mm. A female taken 8 May had 3 embryos 30 mm long.

Groves, C. R. 1994. Effects of timber harvest on small mammals and amphibians in old-growth coniferous forests on the Priest Lake Ranger District, Idaho Panhandle National Forests. [Unpublished report to the Priest Lake Ranger District]. 18 pp. The Nature Conservancy, Boulder, Colorado.

Abstract: Summary of field data collected in survey of small mammals and amphibians in old-growth coniferous forests on the Priest Lake Ranger District, Idaho Panhandle National Forests. Abundance and species richness were estimated on pitfall trapping grids with drift fences at 15 sites representing five replicates of three treatments. 5 shrew species, 1 pocket gopher sp., 6 sp. of mice and vole (including Northern Bog Lemmings), and 3 amphibian sp. were found over a three year period.

Groves, C. and E. Yensen. 1989. Rediscovery of the northern bog lemming (*SYNAPTOMYS BOREALIS*) in Idaho. *Northw. Nat.* 70:14-15.

A single adult male was captured on 14 July 1988 at Cow Creek, Boundary Co., Idaho at 1304 m elevation. The site was at the edge of a sphagnum bog next to an Englemann spruce tree. Dominant vegetation in the bog included: *DESCHAMPSIA CAESPITOSA*, *CAREX ROSTRATA*, *ERIOPHORUM CHAMISSONIS*, *BETULA GLANDULOSA*, *KALMIA MICROPHYLLA*, and *SPHAGNUM* spp. Other small mammals captured at the site included: *ZAPUS PRINCEPS*, *CLETHRIONOMYS GAPPERI*, *SOREX* spp, *TAMIAS RUFICAUDUS*, and *MICROTUS PENNSYLVANICUS*. The lemming was taken during 2 nights of trapping with 32 museum special snap traps and 16 pitfalls. The other Idaho *SYNAPTOMYS* site on Gold Peak Road (Johnson and Cheney 1953) was re-sampled in 1987 but no *SYNAPTOMYS* taken; it was logged sometime between the original capture and the re-trapping attempt in 1987. States that records of *SYNAPTOMYS BOREALIS* captured by Larrison (Larrison 1967; Larrison and Johnson 1981) were actually misidentified *PHENACOMYS INTERMEDIUS*.

Guthrie, R. D. 1968. Paleoecology of a Late Pleistocene small mammal community from interior Alaska. *Arctic* 21:223-244.

SYNAPTOMYS BOREALIS is currently present at the site but was not found in Late Pleistocene deposits. Guthrie is unsure if it is a post-glacial immigrant or was present but not found.

Hall, E. R. 1981. *Mammals of North America*. 2nd edition. 2 vol. John Wiley and Sons.

Identification and distribution information for mammals of North America. *SYNAPTOMYS BOREALIS*: description and measurements; distribution; 9 subspp.

Hall, E. R. and E. L. Cockrum. 1953. A synopsis of the North American Microtine rodents. *Univ. Kansas Publ., Mus. Nat. Hist.* 5:373-498.

Good for synonymies, distribution, subspecies, key, and citations of original descriptions. For *SYNAPTOMYS BOREALIS*: places in subgenus *MICTOMYS* and lists 9 subspecies and their distributions. Gives external measurements as total:118-135; tail:19-27; hind foot:16-22; ear:12-13; weight 32-34 g (n=2). Pelage description.

Hall, F. S. 1932. A historical resume of exploration and survey - mammal types and their collectors in the state of Washington. *Murrelet* 13:63-91.

Gives original citation and information from it on the description of *SYNAPTOMYS TRUEI* (=S. *BOREALIS*) from the Skagit Valley of Washington in 1859.

Hamilton, W. J., Jr. and J. O. Whitaker, Jr. 1979. Mammals of the eastern United States. Cornell University Press. Ithaca, NY. 346 pp.

Listed by order. Useful information concerning distribution, habits. Provides range maps and illustrations. For SYNAPTOMYS BOREALIS: distribution and description only.

Harper, F. 1961. Land and fresh-water mammals of the Ungava Peninsula. Univ. Kansas Publ., Mus. Nat. Hist. 27: includes pp. 55-62.

For SYNAPTOMYS BOREALIS: measurements and description. On 16 June an adult female was trapped on a mossy log in swamp among tall and low willows, dwarf birch, CAREX?, sphagnum, and liverwort. She had 7 embryos (13mm), enlarged mammary glands (2 pair pectoral, 2 pair inguinal, with drawing), and lateral glands slightly developed (10x4.5mm). On 17 July a male was trapped on a rock in a brook flowing through mossy woods. Surrounding vegetation included white spruce, tamarack, alder, willow (tall and low), Labrador tea, VIBURNUM EDULE, CORNUS CANADENSIS, RUBUS, COPTIS GROENLANDICA, VIOLA, TRIENTALIS BOREALIS, USNEA, and SPHAGNUM. He had moss (HYLOCOMIUM PYRENACIACUM) in his mouth. Testes were 8X5mm; lateral glands greatly developed 14X8 and 2mm thick; a less developed glandular area was located between each ear and foreleg. Another male found dead on 13 June had testes 7.5X6mm and lateral glands greatly developed 15X7mm. On the lemmings were found a flea (MEGABOTHRIAS ASIO ASIO) and 3 species of mites (HEMOGAMASUS ALASKENSIS, LAELAPS ALASKENSIS, HAEMOLAEALAPS GLASGOWI).

Heaney, L. R. and E. C. Birney. 1975. Comments on the distribution and natural history of some mammals in Minnesota. Can. Field-Nat. 89:29-34.

Observations on the distribution and natural history of 18 species. SYNAPTOMYS BOREALIS found 10 mi S of Big Falls, an extension of the range in the central U.S. approximately 50 miles to the south of previous records (Wetzel and Gunderson 1949).

Heller, E. 1910. Mammals of the 1908 Alexander Alaska expedition. Univ. Calif. Publ. Zool. 5:321-360.

For SYNAPTOMYS BOREALIS: collected 8 specimens. 3 are from Cordova in "a tangle of rye-grass, stumps, and salmonberry bushes." Five are from Port Nell Juan in open tundra in very swampy situations near the beach.

Hinton, M. A. C. 1926. Monograph of the voles & lemmings (Microtinae). Vol. 1. British Mus. Nat. Hist., London.

Taxonomic discussion of the subfamily. Places SYNAPTOMYS in the group Lemmi and says it is the most primitive of the true lemmings (SYNAPTOMYS, LEMMUS, MYOPUS). Divides the genus in two subgenera (SYNAPTOMYS, MICTOMYS) of which MICTOMYS is the most primitive. Long descriptions of skeletal and dental (rootless cheek teeth) differences with excellent drawings of cheek teeth. Says S. BOREALIS has 8 mammae and S. COOPERI 6. Gives 8 species and 9 forms but says many of doubtful validity.

Hoffmann, R. S., P. L. Wright and F. E. Newby. 1969. Distribution of some mammals in Montana. I. Mammals other than bats. J. Mammal. 50(3): 579-604.

Distribution and specimen records listed for select mammals in Montana. SOREX PREBLEI, SCIURUS NIGER, PEROGNATHUS PARVUS, and PROCYON LOTOR are reported for the first time in Montana. Not extensive data. Two SYNAPTOMYS BOREALIS taken at same site in Glacier NP as Wright (1950) on 20-21

July 1953 but not taken in other of 17 years trapped since 1949. Gives dates, 15 Sep 1953 and 12 Sept 1956 for 2 additional specimens taken at Anaconda Creek, Glacier N.P. (see Weckwerth and Hawley 1962).

Hollister, N. 1912. Mammals of the Alpine Club expedition to the Mount Robson region. Canadian Alpine Journal, Spec. No. pp. 1-44.

SYNAPTOMYS BOREALIS CHAPMANI recorded from Moose Pass, British Columbia, and Moose Pass Branch of the Smoky River, Alberta (in Howell 1927).

Hooper, E. T. and B. S. Hart. 1962. A synopsis of Recent North American Microtine rodents. Misc. Publ. Mus. Zool., Univ. Michigan 120. 68 pp.

Systematic study primarily using glans characteristic and comparing cranial and external characteristics. Includes measurements and description of glans for a wide range of rodents including SYNAPTOMYS BOREALIS. The 2 SYNAPTOMYS species are shown to be closely related and the most closely related to them may be PHENACOMYS INTERMEDIUS.

Howell, A. B. 1927. Revision of the American lemming mice (genus SYNAPTOMYS). N. Amer. Fauna 50. 37 pp.

A taxonomic revision of the genus SYNAPTOMYS. Gives distribution maps, drawings of dental and cranial characteristics, descriptions of the different subspecies (7), Type localities and citations, and lists of specimens. Ecological information is primarily based on SYNAPTOMYS COOPERI.

Ingles, L. G. 1965. Mammals of the Pacific States. Stanford University Press, Stanford, California. 506 pp.

Very brief description, habitat, shaded map, and key to mammals in WA, OR, and CA.

Johnson, M. L. and P. W. Cheney. 1953. SYNAPTOMYS in Idaho and northeastern Washington. Murrelet 34:10.

SYNAPTOMYS BOREALIS was collected at one site each in WA and ID. Two immature specimens (1 male, 1 female) were collected at Sema Meadows, Washington, 3000 ft, "at the edge of open beaver meadows" on 4-5 Aug 1952. Two adults (1 male, 1 female) were collected on Gold Peak Road, Idaho, 4200 ft, in a small bog along a stream on 8 Aug 1952.

Jones, J. K., Jr. and E. C. Birney. 1988. Handbook of mammals of the north-central states. U. Minn. Press, Minneapolis. 346 pp.

Semi-popular account of mammals of the North-Central U.S. with general distribution maps (shading only), description with measurements, some natural history, and selected references. SYNAPTOMYS BOREALIS habitat is primarily bogs and marshy areas, but occasionally occurs in more xeric areas including dry woods and sagebrush. It digs short burrows and uses conspicuous runways. Globular nests of dry vegetation are built above ground in winter and below in summer. They do not hibernate. Food is grasses and sedges. Fecal pellets are bright green. The middle claws are enlarged during winter, presumably an adaptation to living in snow. Breeding season from May-Aug. Females produce several litters per year. Number of young range from 2-8, averaging 4. Females have 4 pair mammae (2 pectoral, 2 inguinal). Presumably northern bog lemmings have 3 maturational pelages and 2 seasonal molts in adults as do other microtines.

Jonkel, C. J. 1959. An ecological and physiological study of pine marten. M.S. Thesis, Montana State Univ., Missoula. 81 pp.

Concluding phase of a long-term (1952-1958) study in Glacier NP. Investigated minimum breeding age, time of implantation, and ensuing time to parturition and continued studies on the relationship between small mammals and marten population densities. 2 individual SYNAPTOMYS BOREALIS trapped at two grids during 2 years.

Koenigswald, W. V., and L. D. Martin. 1984. Revision of the fossil Lemminae (Rodentia, Mammalia). Spec. Publ. Carnegie Mus. Nat. Hist. 9:122-137.

Fossil history of the Lemminae is revised and three genera recognized: LEMMUS, SYNAPTOMYS, and MICTOMYS. DICROSTONYX and LAGURUS are excluded. Speculates Lemminae originated in Eurasia and SYNAPTOMYS immigrated to North America in the late Pliocene. Uses enamel patterns for comparison. Places SYNAPTOMYS BOREALIS in the genus MICTOMYS.

Krebs, C. J. and I. Wingate. 1985. Population fluctuations in the small mammals of the Kluane Region, Yukon Territory. Can. Field-Nat. 99:51-61.

Looks at population changes in small mammals in the Yukon. Caught 7 SYNAPTOMYS BOREALIS in 110,628 snap-trap nights.

Larrison, E. J. 1970. Washington mammals, their habits, identification, and distribution. Seattle Audubon Soc., Seattle, Wash.

Gives brief and anecdotal information about life history, identification, and distribution of Washington mammals. Lists locations for SYNAPTOMYS BOREALIS in Washington including E. Fork Gold Creek [specimens from that site have been re-identified as PHENACOMYS. Use of life history information for bog lemmings from this book is problematical since Larrison had misidentified material from both WA and ID (J.D. Reichel, pers. comm.).]

Larrison, E. J. and D. R. Johnson. 1981. Mammals of Idaho. Univ. Press of Idaho, Moscow. 166 pp.

Gives brief and anecdotal information about life history, identification, and distribution of Idaho mammals. Lists locations for SYNAPTOMYS BOREALIS in Idaho; Larrison states that some specimens lack grooves in the upper incisors [these and perhaps others have been re-identified as PHENACOMYS. Use of life history information for bog lemmings from this book is problematical since Larrison had misidentified material from both WA and ID (J.D. Reichel, pers. comm.).]

Layser, E. F. and T. E. Burke. 1973. The northern bog lemming and its unique habitat in northeastern Washington. Murrelet 54:7-8.

SYNAPTOMYS BOREALIS is described from Bunchgrass Meadows in NE Washington at 5000 ft. Area is a true bog/fen of over a square mile with a few small spruce and fir islands. Plants present included: BETULA GLANDULOSA, CAREX LIMOSA, C. SCOPULORUM, DROSER A ANGLICA, LYCOPIUM SITCHENSE, KALMIA POLIFOLIA, SCHEUCHZERLA PALUSTRIS, SIBBALDIA PROCUMBENS, and SPHAGNUM. Authors list bird and herp spp also present. Present on the site were piles of grass and sedge cuttings at the base of small shrubs and along runways; most common cuttings were CAREX SCOPULORUM. A single bog lemming was captured during 140 snaptrap nights on 10-11 July 1972. Suggest threats to population may include: overgrazing, compaction of snow (destroying runways and nests) by snowmobiles, and impoundments which could flood the area.

Linzey, A. V. 1983. SYNAPTOMYS COOPERI. Mammalian Species 210:1-5.

Good summary of available information.

Linzey, A. V. 1984. Patterns of coexistence in SYNAPTOMYS COOPERI and MICROTUS PENNSYLVANICUS. Ecol. 65:382-393.

SYNAPTOMYS are excluded from preferred habitats by MICROTUS. The following patterns were observed: 1) In undisturbed sympatric populations, microhabitat partitioning was observed when habitat was marginal for voles. 2) Lemming microhabitat had more trees and shrubs when voles were present. 3) If vole populations declined, lemmings shifted into habitat previously occupied by voles. 4) Removal of voles from a grid resulted in immediate colonization by lemmings. 5) A year following lemming removal, former lemming habitat remained empty despite an increasing vole population. 6) Food of lemmings was less digestible than voles on grids where both occurred. 7) When voles were removed from a grid, lemming diets became more similar to voles (72 vs 37%).

Lyon, M. W., Jr. and W. H. Osgood. 1909. Catalogue of the Type specimens of mammals in the United States National Museum, including the Biological Survey Collection. U. S. Natl. Mus. Bull 62. 325 pp.

Lists the Type specimens with citations of original description, what is present in collection and the state of the material.

Manville, R. H. and S. P. Young. 1965. Distribution of Alaskan mammals. Bur. Sport Fish Wildl. Circular 211. 74 pp.

Provides dot range map for SYNAPTOMYS BOREALIS. Describes habitat as wet tundras and sphagnum bogs, occasionally dry or moist meadows.

Martell, A. M. 1974. A northern range extension for the northern bog lemming, SYNAPTOMYS BOREALIS BOREALIS (Richardson). Can. Field-Nat. 88:348.

Near Inuvik, 4 specimens (3 M, 1 F) captured in 75,000 trap-nights.

Mead, J. I., C. J. Bell, and L. K. Murray. 1992. MICTOMYS BOREALIS (northern bog lemming) and the Wisconsin paleoecology of the east-central Great Basin. Quaternary Res. 37:229-238.

Summarizes the paleo records of northern bog lemmings with a dot map and citations. Indications are that the species in the Snake Range on the NV/UT border was only locally present in or near mesic spruce forest habitat 24,000 to 15,000 yrs BP.

Millar, J. S., D. G. L. Innes, and V. A. Loewen. 1985. Habitat use by non-hibernating small mammals of the Kananaskis Valley, Alberta. Can. Field-Naturalist 99:196-204.

Caught one northern bog lemming in "mature subalpine forest" during 26,700 trapnights.

Merriam, C. H. 1896. Revision of the lemmings of the genus SYNAPTOMYS, with descriptions of new species. Proc. Biol. Soc. Wash. 10:55-64.

Descriptions and some locations. First to break SYNAPTOMYS into two subgenera.

Miller, G. S., Jr. 1896. Genera and subgenera of voles and lemmings. N. Amer. Fauna 12. 84 pp.

Gives description of both species of SYNAPTOMYS, including pelage, measurements, skull, and teeth.

Morlan, R. E. 1989. Paleoecological implications of Late Pleistocene and Holocene microtine rodents from the Bluefish Caves, northern Yukon Territory. Can. J. Earth Sci. 26:149-156.

A single SYNAPTOMYS BOREALIS found (in Holocene birch phase sediment) among 10s of thousands of small mammal remains. It was not found in Pleistocene deposits. Currently inhabits the area.

Munro, J. A. 1947. Observations of birds and mammals in central British Columbia. Occasional Papers B.C. Prov. Mus. 6.

For SYNAPTOMYS BOREALIS: 2 locations in central BC; female w/ 4 embryos taken 15 May; all trapped in runways through VACCINIUM; associated species included MICROTUS PENNSYLVANICUS and CLETHRIONOMYS GAPPERI.

Osgood, W. H. 1900. A biological reconnaissance of the Yukon River Region: annotated account of mammals. N. Amer. Fauna 19:1-45.

Collected SYNAPTOMYS DALLI (=BOREALIS) at several locations. At one location near Lake Lebarge they were in long grass at the edge of a small pond, while other locations were in cold boggy places near small streams. Gives description and measurements.

Osgood, W. H. 1904. A biological reconnaissance of the base of the Alaska Peninsula. N. Amer. Fauna 24. 86 pp.

Collected 24 SYNAPTOMYS DALLI (=BOREALIS) of all age and sex categories. Found much age variation in skull measurements. Usually found in small colonies "in very wet swampy places, preferably in wet moss." One area was a small boggy place partially filled with dead logs and branches and overgrown with moss. Says they make runways slightly smaller than MICROTUS and usually in "moss rather than grass and weeds." Gives description and measurements.

Osgood, W. H. 1904. Natural history of the Cook Inlet region, Alaska. N. Amer. Fauna 21:51-81.

Collected 1 SYNAPTOMYS DALLI (=BOREALIS) a small peat bog near Hope. Gives description and measurements.

Osgood, W. H. 1907. Some unrecognized and misapplied names of American mammals. Proc. Biol. Soc. Wash. 20:43-52.

Redescribes Type specimen and gives some of original description of ARVICOLA (=SYNAPTOMYS) BOREALIS from Richardson (1828).

Osgood, W. H. 1909. Biological investigations in Alaska and Yukon Territory. N. Amer. Fauna 30. 86 pp.

For *SYNAPTOMYS BOREALIS*: "Rather rare, only 4 specimens taken" in E Central AK. 1 taken in a "grassy swamp" other 3 near timberline at the head of Seward Creek. In the Ogilvie Range 2 were taken in "cold Swamps." In the MacMillan region 5 were taken in a sphagnum swamp near mouth of Russell Creek.

Pearson, D. E. 1991. The northern bog lemming in Montana and the contiguous United States: Distribution, Ecology and relic species theory. Unpubl. Senior Thesis, Univ. Mont., Missoula. 33 pp.

SYNAPTOMYS surveys were conducted with Sherman live traps at 16 sites. Describes 4 new lemming capture sites in Glacier National Park (McGee Meadows (1 animal), Little McGee Meadows (2), Numa Ridge Bog (1), and McDonald Creek (1)) and a new specimen from the known Shoofly Meadows site [see Adelman 1979]. The McDonald Creek site was part of a general small mammal project and has been surveyed on multiple occasions but only a single lemming has been captured. This site is in old-growth western hemlock (*TSUGA HETEROPHYLLA*) without typical bog/fen habitat (includes plant list). The other sites are all typical bog/fen habitat with thick sphagnum moss mats and are structurally described in some detail with vegetation mentioned to the generic level. Other small mammals captured at lemming sites included: *CLETHRIONOMYS GAPPERI*, *PEROMYSCUS MANICULATUS*, *SOREX* spp., *MICROTUS* spp., *TAMIAS* spp. Trapping success was 1 lemming per 806 Sherman live trap-nights (16 sites with 4030 TN). Mortality rate for lemmings was 60% (93 of 155). Tracking board sampling was tried, but lemming dropping could not be differentiated from *MICROTUS* (*CLETHRIONOMYS* and *SOREX* could be). Includes a summary of most of the specimens taken in the lower 48 states. Good discussion of research methodologies and distribution.

Peterson, R. L. 1966. The mammals of eastern Canada. Oxford University Press. Toronto, Canada. 465 pp.

Good general reference; body measurements; references. For *SYNAPTOMYS BOREALIS*: rarest rodent in collections for eastern Canada. Description. Notes that 2 specimens taken in mid-January and mid-April at Indian House Lake, Quebec, showed extreme enlargement of 2 middle claws on the front feet; it is unknown if this is normal since only 2 specimens have ever been taken during this season. A series of 6 specimens taken in northern Quebec were from a dry, partly wooded habitat. Specimens of three pregnant females in the Royal Ontario Museum taken in June had 4, 4, and 7 embryos.

Preble, E. A. 1899. Description of a new lemming mouse from the White Mountains, New Hampshire. Proc. Biol. Soc. Wash. 13:43-45.

Description of the subspecies *SYNAPTOMYS BOREALIS SPHAGNICOLA* based on one specimen trapped at Fabyans (1600') near the base of Mt. Washington on 29 June 1898. Habitat "is swampy and quite densely carpeted with moss..." Associated species included *MICROTUS*, *PEROMYSCUS*, *BLARINA*, *CLETHRIONOMYS*, *ZAPUS HUDSONICUS*, and *NAPOZAPUS INSIGNUS*.

Preble, E. A. 1902. A biological investigation of the Hudson Bay Region. N. Amer. Fauna 22. 140 pp.

For *SYNAPTOMYS BULLATUS* (= *BOREALIS*): Only trapped 2 specimens, one near Norway House. The other was a female with 6 embryos in a swamp bordering the Echimamish River on June 25.

Preble, E. A. 1902. Descriptions of new species of SYNAPTOMYS and PHENACOMYS from MacKenzie, Canada. Proc. Biol. Soc. Wash. 15:181-182.

Description of new species SYNAPTOMYS BULLATUS (=S. BOREALIS) from Great Slave Lake, Canada from a skin and skull of adult male.

Preble, E. A. 1908. A biological investigation of the Athabaska-Mackenzie Region. N. Amer. Fauna 27. 574 pp.

For SYNAPTOMYS BOREALIS: took 8 near site (Ft. Franklin) of those originally described by Richardson (1829) and quotes extensively from that paper. Caught one female with 4 embryos. Habitat at various sites where lemmings were captured include: 1) border of a small meadow; 2) wet swamp; 3) near small muskeg ponds; and 4) marsh. Says Loring found SYNAPTOMYS rather common in October in a sphagnum swamp and caught about a dozen. Gives measurements and descriptions and merges S. DALLI with S. BOREALIS as S.B. DALLI.

Prince, L. A. 1942. SYNAPTOMYS BOREALIS from Fort Severn, Hudson Bay, Ontario. J. Mammal. 23:216.

An immature male SYNAPTOMYS BOREALIS was trapped at Ft. Severn on 11 July 1940. Was taken in a "water trap" on alder and willow bordered bank of a stream draining a black spruce bog. Gives measurements of the single specimen.

Rand, A. L. 1945. Investigations on the Canal Road, Yukon and Northwest Territories, 1944.. Natl. Mus. Can. Bull. 99.

For SYNAPTOMYS BOREALIS: 7 taken in 400 trap-nights in open, wet moss, sedge, willow and spruce swamp on Lapie River. Also taken were MICROTUS PENNSYLVANICUS. At Mount Sheldon 12 were taken in marshy sedge fringing ponds in a dwarf birch flat 11-15 Aug. On 22-25 Aug 7 were taken in a wet grassy glade on the Macmillan River. In all cases the species was very local, with none being caught during extensive trapping in the surrounding area.

Rand, A. L. 1945. Mammals of Yukon. Natl. Mus. Can. Bull. 100. 93 pp.

For SYNAPTOMYS BOREALIS: description and measurements. States "...scarce animal, found in grass and sedge areas in bogs and marshes where it makes runways" but no indication this is based on observations or literature or?

Reichel, J. D. 1984. Ecology of Pacific Northwest alpine mammals. Unpubl. Ph.D. Thesis, Wash. State U., Pullman. 91 pp.

Information on distribution, dispersal, population structure and habitat use of alpine areas in WA and OR by small mammals. For SYNAPTOMYS BOREALIS one new site, and additional information on another site (Wilson et al. 1980), is given. At sites where lemmings were trapped, Gypsy Peak (918 snap trap-nights) and Slate Peak (1173 snap trap-nights) each produced a single animal (one male, one female). The Gypsy Peak site was fellfield habitat, while the Slate Peak site was a sedge/graminoid wet meadow. Lemmings were not relocated at the Cascade Creek site of Shaw (1930).

Reichel, J. D. and S. G. Beckstrom. 1993. Northern bog lemming survey: 1992. [Unpublished report] Montana Natural Heritage Program. Helena, MT. 64 pp.

Survey of 21 sites in western Montana for *SYNAPTOMYS BOREALIS* using primarily snaptraps (some comparisons using live traps and pitfalls). Found 5 new sites including the southern-most sites in western North America (map). Compares baits. Lemmings were captured at elevations from 4760-6520 feet. All sites had thick mats of sphagnum moss present. Bog birch and/or a dwarf willow were present at all sites. At sites where lemmings were found, it took 5-140 trap-nights for the first lemming capture; in contrast, 240-556 trap-nights were tabulated at sites where none were captured. Other species captured at sites with bog lemmings included: *MICROTUS PENNSYLVANICUS*, *CLETHRIONOMYS GAPPERI*, *SOREX*, and *PHENACOMYS INTERMEDIUS*. Includes research needs and methods, management recommendations, and references.

Reichel, J. D. and S. G. Beckstrom. 1994. Northern bog lemming survey: 1993. Montana Natural Heritage Program. Helena, MT. 87 pp.

During the 1993 field season small mammals were surveyed for at 30 sites, capturing northern bog lemmings at 5 new sites. One site, Wood Creek on the Rocky Mountain Ranger District, Lewis and Clark NF, is the eastern-most site known in Montana and 90 km from the nearest previously known site. Three sites on the Kootenai NF were in the Sunday Creek drainage, 1-6 km from the site discovered there in 1992. The last new site, also on the Kootenai NF, was found at Cody Lake, 32 km from the nearest known site. Despite surveys at 5 sites with apparently good-excellent habitat on the Flathead NF, no new lemming sites were found there. The total number of known bog lemming sites in Montana is 17, the most sites in any of the lower 48 states. All sites found in 1993 had moss mats at or near the trap location. Known sites in Montana range in size from 1 to 340 acres. The best habitat predictor for potential bog lemming sites in Montana is the presence of extensive, thick moss mats, particularly sphagnum moss. More sites with apparently good quality habitat were trapped unsuccessfully in 1993 than 1992; whether lemmings are actually present at some or all of those sites is unknown.

Repenning, C. A. and F. Grady. 1988. The Microtine rodents of the Cheetah room fauna, Hamilton Cave, West Virginia, and the origin of *SYNAPTOMYS*. U.S. Geol. Survey Bull. 1853:1-32.

Give history of bog lemmings, starting with ancestral form from eastern Europe 4 million yrs ago. Has found evidence that *SYNAPTOMYS COOPERI* evolved from the *MICROTOMYS* line (which is 3 million yrs old) only about 600,000 yrs ago.

Rhoads, S. N. 1894. Descriptions of a new subgenus and new species of arvicoline rodents from British Columbia and Washington. Proc. Acad. Nat. Sci. Philadelphia 1894:282-288.

Description of Topotype of *ARVICOLA BOREALIS* (= *SYNAPTOMYS BOREALIS*) of an adult female taken near Ft. Anderson, north of Great Bear Lake. [NOTE: drawing of dentition looks like *MICROTUS* not *SYNAPTOMYS BOREALIS*].

Rose, R. K. and A. M. Spevak. 1978. Aggressive behavior in two sympatric microtine rodents. J. Mammal. 59:213-216.

SYNAPTOMYS were less aggressive and showed more avoidance than *MICROTUS* in lab encounter trials.

Saunders, W. E. 1927. PHENACOMYS UNGAVA in Ontario. J. Mammal. 8:305-307.

Notes on captures of PHENACOMYS UNGAVA (=INTERMEDIUS) and SYNAPTOMYS. Caught a SYNAPTOMYS almost daily.

Scott, P. A. and R. I. C. Hansell. 1989. The lemming community on the lichen-heath tundra at Churchill, Manitoba. Can. Field-Nat. 103:358-362.

Describes lemming community by species and habitat. For SYNAPTOMYS BOREALIS only 2 were captured (2360 trap-nights), one each in a CAREX-moss-SALIX community and a SALIX community. Other species present on the sites of capture included: DICROSTONYX RICHARDSONI and MICROTUS PENNSYLVANICUS.

Seton, E. T. 1909. Life-histories of northern animals. An account of the mammals of Manitoba. Vol. 1. Charles Scribner's Sons, New York.

Repeats other literature briefly (description, distribution, habitat of cold sphagnum bogs). No original information except "shy, secretive, nocturnal" but no citation or indication of where the information came from.

Severinghaus, W. D. 1981. Methods useful in distinguishing Microtines sympatric with the subgenus PEDOMYS. J. Tenn. Acad. Sci. 56:20-22.

Shaw, W. T. 1930. The lemming mouse in North America and its occurrence in the state of Washington. Murrelet 11:7-10.

SYNAPTOMYS BOREALIS (immature) was first captured in Washington in "the Skagit Valley, Skagit Co. on 6 Aug 1859. At the head of Cascade Creek a single individual was taken on 30 Jul 1923 and 11 more during summer 1926; none were trapped in 1928 and 1929 at the same location. The location was at 5000 ft at the head of the drainage in a bog-like area. The bog had many logs from avalanches, PERNASSIA FIMBRIATA, CAREX SPECTABILIS, HABENARIA SACCATA, TOFIELDIA OCCIDENTALIS, MIMULUS TILINGI, M. LEWISII, and a thick carpet of moss (HYPNUM).

Smith, H. C. 1993. Alberta mammals, an atlas and guide. Prov. Mus. Alberta, Edmonton. 238 pp.

Good general information guide with keys, dot maps, habitat, status in Alberta, and measurements. For SYNAPTOMYS BOREALIS: identifying characteristics and description; mapped locations in N part of Alberta down W side in mountains to within 150 km of US border; status is uncommon though widely distributed; habitat is "moist meadows and bogs;" table with weight and external measurements for male (n=15) and female (n=4) lemmings.

Smith, R. W. 1940. The land mammals of Nova Scotia. Amer. Midl. Nat. 24:213-241.

Short accounts of new records during 1925-1940. SYNAPTOMYS COOPERI was collected but S. BOREALIS was not.

Smits, C. M. M., B. G. Slough and C. A. Yasui. 1989. Summer food habits of sympatric arctic foxes, *ALOPEX LAGOPUS*, and red foxes, *VULPES VULPES*, in the northern Yukon Territory. *Can. Field-Nat.* 103:363-367.

Diets of both foxes were similar with small mammals predominating. *SYNAPTOMYS BOREALIS* was up to 3.7% frequency in the diet at some locales for Arctic Fox.

Soper, J. D. 1948. Mammal notes from the Grande Prairie - Peace River region, Alberta. *J. Mammal.* 29:49-64.

For *SYNAPTOMYS BOREALIS*: "scarce and local." One male taken in moist spruce woods near shore of Lake Ray, Alberta on 6 July 1944. Measurements and pelage description.

Soper, J. D. 1973. The mammals of Waterton Lakes National Park Alberta. *Can. Wildl. Serv. Rep. Series* 23:1-57.

No *SYNAPTOMYS BOREALIS* have been found in Park. Short summary of nearby locations and general information.

Stenseth, N. C., and R. A. Ims (eds). 1993. The biology of lemmings. *Linnean Society Symposium Series* 15, 683 pp.

A series of articles by various authors on evolutionary history, taxonomy, distribution, population dynamics, food, growth, reproduction, and Intra- and Interspecific relationships. Also included are sections on the history of lemming research, future research needs, and research techniques. Little information on northern bog lemmings.

Swath, H. S. 1922. Birds and mammals of the Stikine River region of northern British Columbia and southeastern Alaska. *Univ. Calif. Publ. Zool.* 24:125-314.

For *SYNAPTOMYS BOREALIS*: Great Glacier on Stikine River, B.C.; 3 males caught; description; habitat-alder thicket.

True, F. W. 1894. Diagnoses of new North American mammals. *Proc. U.S. Natl. Mus.* 17:241-243.

Description of Type of *MICTOMYS INNUITUS* (= *SYNAPTOMYS BOREALIS*) collected Fort Chimo, Ungava, Labrador by L.M. Turner spring 1884. Nursing female.

Weckwerth, R. P. and V. D. Hawley. 1962. Marten food habits and population fluctuations in Montana. *J. Wildl. Manage.* 26(1):55-74.

A 5 year investigation of the relationships between marten population fluctuations, food habits, & prey densities in Glacier NP. Foods were mostly mammals—Cricetidae. Varied with season & availability; population trends strongly influenced by prey densities. *SYNAPTOMYS BOREALIS* was trapped in 2 of 5 years trapping was done. Marten scats contained *SYNAPTOMYS BOREALIS* at a 1.6% frequency during the study, while lemmings comprised only 2 of 223 small mammals trapped.

Wetzel, R. M. and H. L. Gunderson. 1949. The lemming vole, *SYNAPTOMYS BOREALIS*, in northern Minnesota. *J. Mammal.* 30:437.

Gives locations for 1 immature female (5 Aug 1932) and 1 adult male (27 July 1948).

Wilson, C., R. E. Johnson, and J. D. Reichel. 1980. New records for the northern bog lemming in Washington. *Murrelet* 61:104-106.

Describes 3 new sites for *SYNAPTOMYS BOREALIS* in Washington. One individual (immature, sex unknown) was collected 22 Jun 1979 in a wet (standing water) hummocky sedge meadow with willow and bog birch at 6100 ft. On 25 June 1980 an adult male was collected at a similar site (less hummocky, no bog birch) at 5400 ft, about 6 mi from the first site. At both these sites *MICROTUS PENNSYLVANICUS* was also trapped. An immature female was captured at the third site (extreme NE WA) at 7250 ft on 23 Aug 1980. The habitat was a barren alpine ridge (15% vegetative cover) at least 900 vertical ft above the nearest boggy meadow.

Wright, P. L. 1950. *SYNAPTOMYS BOREALIS* from Glacier National Park, Montana. *J. Mammal.* 31(4):460.

First record of northern bog lemming in Montana. Adult male caught. HABITAT: a swampy area; plants included Englemann spruce, timothy, false hellebore, alder, nannyberry, cow parsnip, horsemint, yellow monkey flower, and snowberry. ASSOCIATED SPECIES included: *MICROTUS PENNSYLVANICUS* and *SOREX VAGRANS*. TRAPPING SUCCESS: 1 lemming in 62 trap-nights; not found at same site during 200 trap-nights 2 months later.

Wrigley, R. E. 1974. Ecological notes of animals of the Churchill region of Hudson Bay. *Arctic* 27:201-214.

One *SYNAPTOMYS BOREALIS* collected in sedge-moss tundra 35 mi. NW of Churchill.

Youngman, P. M. 1964. Range extensions of some mammals from northwestern Canada. *Natl. Mus. Can., Nat. Hist. Paper* 23. 6 pp.

For *SYNAPTOMYS BOREALIS*: lists far north records including Old Crow and Rampart House, Yukon, the farthest known north records for the species at the time.

Youngman, P. M. 1968. Notes on mammals of southeastern Yukon Territory and adjacent Mackenzie District. *Natl. Mus. Can. Bull.* 223:70-86.

For *SYNAPTOMYS BOREALIS*: collected in the N. W. T.: 1) a male and nonparous female in a hot spring meadow with *MICROTUS PENNSYLVANICUS* and *M. LONGICAUDUS* at 4000 ft, Flat River; 2) one at a marsh at Glacier Lake, 2500 ft; in the Yukon: 3) a male in riparian brushlands 5 mi E of Little Hyland River, 6000 ft and a male at 4000 ft; 4) 11 males and 4 females in white spruce at North Toobally Lake, 2200 ft.

Youngman, P. M. 1975. Mammals of the Yukon Territory. Natl. Mus. Canada, Publ. Zool. 10. 192 pp.

Very good general reference with sections on environmental influences, vegetation and refugium effects on mammal distribution. Species accounts have detailed taxonomic synonymies, dot maps, external and skull measurements, and remarks on fossils, habitat, and ecology. For *SYNAPTOMYS BOREALIS*: distributed throughout the wooded portion of the Yukon. Has external and skull measurements of males (n=18) and females (n=5-6); pelage description. Suggests that *S. BOREALIS* speciated in a south-western refugium and is a post-glacial immigrant to the north. Collected in the Yukon "between 800 and 6000 ft mostly in bogs and marshes." Stated 10 pregnant females averaged 4.4 (3-6) embryos.